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TO: H. Garrett

FROM: Logistics and Technical Information Division

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Simulations of Solar Wind Plasma Flow Around a Simple Solar Sail

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TITLE
SIMULATIONS OF SOLAR WIND PLASMA FLOW AROUND A SIMPLE SOLAR SAIL

OTHER AUTHORS
Joseph Wang

☐ Premeeting publication
☒ Publication on meeting day
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☐ Handouts

KEY WORDS FOR INDEXING *(Separate items with commas)*
Spacecraft Charging, Solar Sails, Solar Wind

THIS WORK: ☐ Covers new technology not previously reported
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SIMULATIONS OF SOLAR WIND PLASMA FLOW AROUND A SIMPLE SOLAR SAIL

INTERACTIONS OF SPACECRAFT AND SYSTEMS WITH THE NATURAL AND INDUCED PLASMA ENVIRONMENT

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In recent years, a number of solar sail missions of various designs and sizes have been proposed (e.g., GEOSTORM). Indeed various groups, both private and governmental, are in the process of building either flight or prototype solar sails. Of potential importance to these missions is the interaction of the ambient solar wind plasma environment with the sail. The solar wind plasma in interplanetary space can vary over a wide range: from <1 cm^{-3} to ~80 cm^{-3} in density, from ~200 km/s to over 2000 km/s in velocity, and from 0.5 eV to ~100 eV in temperature. Assuming a "typical" 1 AU solar wind environment of 400 km/s velocity , 3.5 cm^{-3} density, ion temperature of ~10 eV, electron temperature of 40 eV, and an ambient magnetic field strength of 10^{-4} G, we have carried out a first order estimate of the plasma interaction with square solar sails on the order of the sizes being considered for a GEOSTORM mission (50 m x 50 m and 75 m x 75 m corresponding to ~2 and ~3 times the Debye length in the plasma). First, the crude current balance for the sail surface immersed in plasma environment and in sunlight was used to estimate the surface potential of the model sails (the surfaces in this initial study are assumed to be made of thin, uniformly conducting aluminum). This gives surface potentials of ~10 V positive relative to the solar wind plasma. A 3-D, Electrostatic Particle-in-Cell (PIC) code was then used to simulate the solar wind flowing around the solar sail. It is assumed in the code that the solar wind protons can be treated as particles while the electrons follow a Boltzmann distribution. The electric field and particle trajectories are solved self-consistently to give the proton flow field, the electrostatic field around the sail, and the plasma density in 3-D. Representative figures are given below. The sail is found to be surrounded by a plasma sheath within which the potential is positive compared to the ambient plasma and followed by a separate plasma wake which is negative relative to the plasma. This structure departs dramatically from a negatively charged plate such as might be found in the Earth's ionosphere on the night side where both the plate and its negative wake are contiguous. The talk will discuss the implications of these findings and discuss further areas of study in solar wind/solar sail plasma interactions.

Positively Solar Sail in Solar Wind

Negatively Charged Plate in Solar Wind